COS320: Compiling Techniques

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- Reminder: HW1 due today
- HW2 on course webpage. Due March 5
  - You will implement:
    - A simulator for X86lite machine code
    - An assembler
    - A loader
  - You can expect this assignment to require more time than HW1. Start early!
  - You may work individually or in pairs

Last time: let-based IR

Each instruction has at most three operands ("three-address code")

`<instr>` ::=	`let <uid> = <operand> <op> <operand>;`	Instructions
	| `load <uid> = <var>;`	
	| `store <var> = <operand>;`	
`<operand>` ::=	`<uid>` | `<integer>`	Operands
`<op>` ::=	`+` | `*`	Operations

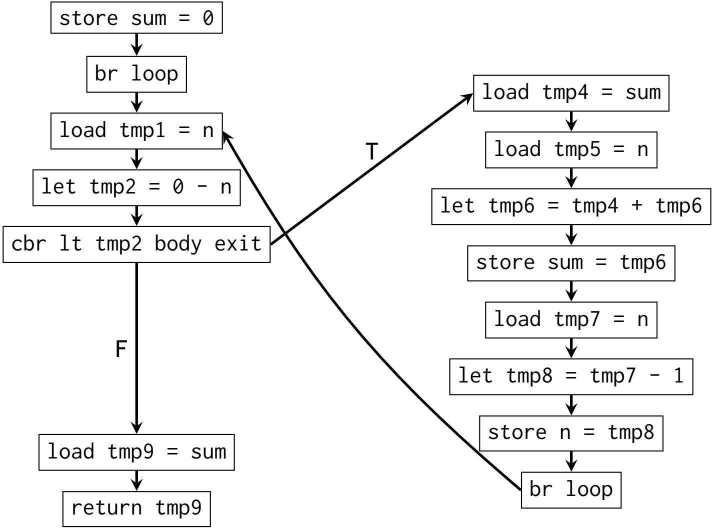
Control Flow

Concrete syntax

```
<control> ::= br <label>                                   Branch
              cbr <cc> <operand> <label> <label>           Conditional branch
              return <operand>                             Return
     <cc> ::= EqZ | LeZ | LtZ
  <block> ::= <instr><block> | <control>
<program> ::= <program><label>: <block> | <block>
```

Control Flow Graphs (CFG)

```
int sum_upto(int n) {
  int sum = 0;
  while (n > 0) {
    sum += n;
    n--;
  }
  return sum;
}
```



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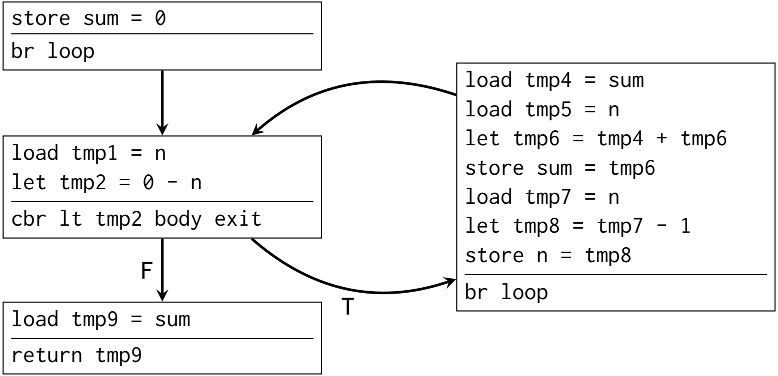

- Control flow graphs are a graphical representation of the control flow through a procedure
- A *basic block* is a sequence of instructions that
  1. Starts with an *entry*, which is named by a label
  2. Ends with a control-flow instruction (`br`, `cbr`, or `ret`)
     - the *terminator* of the basic block
  3. Contains no interior labels or control flow instructions
- A *control flow graph* (CFG) for a procedure P is a directed, rooted graph where
  - The nodes are basic blocks of P
  - There is an edge $BB_i \rightarrow BB_j$ iff BB_j may execute immediately after BB_i
  - There is a distinguished entry block where the excution of the procedure begins

- CFG models all program executions
  - Every execution corresponds to a path in the CFG, starting at entry
    - Path = sequence of basic blocks $B_1, ..., B_n$ such that for each i, there is an edge from B_i to B_{i+1}
    - *Simple* path = path without basic blocks
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  - (But not vice-versa!)
- Simple application: dead code elimination
  1. Depth-first traversal of the CFG
  2. Any *unvisited node* is removed
- Graph structure used extensively in optimization (data flow analysis, loop recognition, ...)

Why basic blocks?

- Control flow graphs may be defined at the instruction-level rather than basic-block level
- However, there are good reasons for using basic blocks
  - More compact
  - Some optimization passes ("local" optimizations) operate @ basic block level

Constructing a CFG

- Traverse statements in IR from top to bottom
  - Find *leaders*
    - First statement
    - First statement following a label
  - Basic block = leader up to (but not including) next leader
- Can also construct CFG directly from AST

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- More efficient strategy: elide jumps by ordering blocks appropriately
  - A *covering set of traces* is a set of traces such that
    - Each trace is simple (loop free)
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- Basic algorithm: depth-first traversal of the CFG
  - If at least one successor is *unvisited*, elide jump and place the successor next in sequence
  - If all successors are visited, terminate branch